Heat transport in low-dimensional materials

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The integration of nanomaterials into various applications is crucial in pushing the boundaries of modern technology, as they demonstrate enhanced characteristics when compared to their bulk counterparts. It is well known that traditional 3D materials, like silicon, experience a substantial reduction in thermal conductivity when thinned down to nanometer thickness, due to increased phonon scattering at the surface [1]. The thermal properties of nanomaterials are gaining increasing significance, particularly in the context of efficient heat dissipation necessary for the development of high-performance electronic devices, energy conservation, and the prevention of thermal damage. Here, we measure the thermal conductivity of free-standing 2D transition metal dichalcogenides (TMDs) and 1D carbon nanotube (CNT) films using all-optical Raman thermometry. Our results on the TMD $MoSe_2$ reveal a weak influence of flake thickness on $MoSe_2$ in-plane thermal conductivity from bulk (~40 W/m/K) down to monolayer limit (~20 W/m/K), with sub-nm thickness. Meanwhile, the thinnest TMD flakes exhibit efficient heat dissipation to air molecules due to large surface-to-volume ratio, with heat transfer coefficients as large as 60,000 $W/m^2/K$ [2]. For CNT films, we find an enhanced thermal conductivity of double-walled (~50 W/m/K) as compared to single-walled (~10 W/m/K) CNT networks, attributed to the additional wall, which likely gives rise to additional heat-carrying phonon modes and provides a certain resilience to defects [3]. In conclusion, our results contribute to a more comprehensive understanding of the intrinsic thermal properties of nanomaterials and shed light on efficient heat dissipation strategies in next-generation (opto)electronic devices for various technological applications.

References

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